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Decoding Vitruvius — Modulation of a Sequenced Nominal Value of a Fixed Module by *Ad Triangulum* Geometry

Dekodiranje Vitruvija — modulacija redane nazivne vrijednosti zadanog modula geometrijom *ad triangulum*

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ABSTRACT

The sequencing of circles congruent with a (divided) column diameter – a visualization of the Vitruvian concept of a fixed module – is expanded by the inclusion, in the same scale, of geometric figures intrinsic to the *ad triangulum* method. The indication of continuous use of the proposed proportional system from Classical Antiquity to the 18th century points to the existence of a single canon for designing intercolumnar plane and fenestration.

KEYWORDS

proportional systems, module, Vitruvius, *ad triangulum*, intercolumniation, fenestration

APSTRAKT

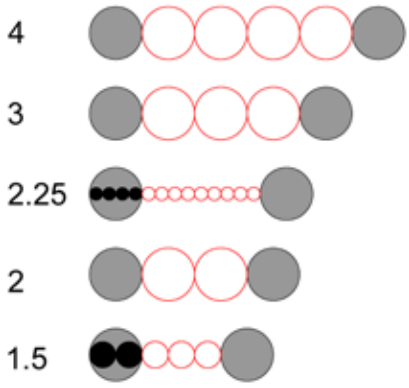
Redanje krugova sukladnih (podijeljenom) promjeru stupa – predodžba Vitruvijevog koncepta zadanog modula – prošireno je uvrštenjem, u istoj skali, geometrijskih likova svojstvenih metodi *ad triangulum*. Naznake neprekidnog korištenja predloženog proporcijskog sustava klasične starine sve do 18. stoljeća upućuju na postojanje jedinog pravila za oblikovanje međustupovne ravnine i fenestracije.

KLJUČNE RIJEČI

proporcijski sustavi, modul, Vitruvije, *ad triangulum*, međustupovlje, vrata i prozori

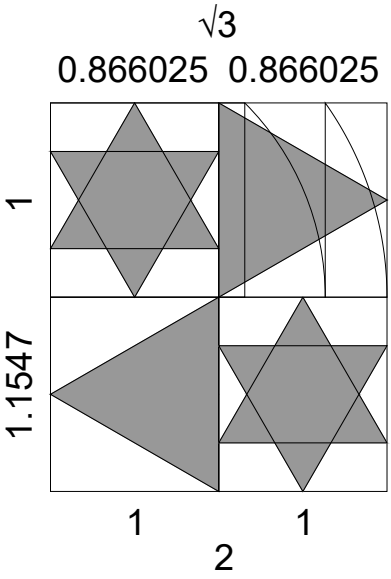
To detect the presence and use of proportions-as-ratios, presumed in historical architecture, are objectives that have long stimulated academical research. Proportional systems are generally divided into geometrical and numerical, i.e., arithmetical. The first category, commonly considered to be medieval, is based on the principle of division of the whole by geometric figures, to which irrational numbers are intrinsic.[1] On the contrary, in the concept of a module, the principle of addition is applied.[2] Since the purpose of a modular system is to define a new unit (module) for measuring lengths, it is similar to standard measuring systems – just based upon another unit that allows expression of any magnitude as a multiple or a fraction, leading to an arithmetical sequence of numbers.[3] Therefore, it is considered to be a rational approach inherent to the revived Classical thought of the Renaissance humanism.[4]

The earliest known mention of the concept is in *De Architectura Libri Decem* by the Roman architect and military engineer Vitruvius, the only treatise on architecture to survive from antiquity. Since the Renaissance it has been regarded as the first book on architectural theory, which is the "*ability to demonstrate and explain the productions of dexterity on the principles of proportion.*" (Vitruvius, Book I, Chapter 1, *1*), as well as a major source on the canon of Classical architecture.[5] Regardless of the stated importance of geometry and the emphasized necessity of knowing the theory of geometry as well as geometric methods relating to issues of symmetry (I, 1, *3-4*), integer multiples or simple fractions based on anthropometry are consistently used to realize the concept of *symmetria*, provided that a certain part is defined as a standard (III, 1, *9*). Accordingly, 5 *intercolumnia* Vitruvius found appropriate for the Classical orders (except the Doric) – bearing the nominal values (hereafter: NV) of >3, 3, 2¼, 2 and 1½ diameters of the column – classify a temple as *araeostylos*, *diastylos*, *eustylos*, *systilos* and *pycnostylos* (III, 3, *2-6*). Since the diameter represents a module in the fragmented theory (III, 3, *7*) it follows that the NV of intercolumniation inevitably effects the proportions of the whole edifice. Regarding the determination of the total height of a column (III, 3, *10*), the column diameter is the fixed parameter in canonized procedure – the multiplications being exclusively of rational numbers. Considering NVs of Vitruvian integers for *intercolumnium*, the principle of a sequence of the multiplied column diameter with a NV of 1 (according to its shape is represented by a circle) is implied. Therefore, it is necessary to perform a simple logical operation in the case of the non-integer NV, namely the division of column diameter into 4 or 2 congruent modules of the same NV of 1 (Fig. 1). Sequences of 9 or 3 of that NV result in the specified NV of 2.25 (9/4) or 1.5 (3/2). The congruence in scale, regarding denser colonnades of the Greek Doric order, reinterprets Vitruvius' somewhat strange statement about the division of, logically, the bottom diameter of the Doric column into 2 modules (IV, 3, *4*) – although the supposed method for determining proportions of a Greek Doric temple, that also includes the intercolumniation, has been linked to the *stylobate* and later to the *krepis* or to the uniform rhythm of triglyphs and metopes with the mutual proportional ratio.[6] Regarding the Vitruvian NVs – if only the clearly stated application of the concept for determining intercolumniation is considered – that do not correspond to NVs in a large number of extant colonnades, discrepancies could be the result of symmetry-related adaptation to conditions depending on the architect's skill (VI, 2, *1* and *4*), but they could also be attributed to an imprecise execution or interventions to the subsequent copies of the text. Therefore, unsurprisingly, many scholars in search of a formula for determining proportions in the Classical architecture apply their own systems in a certain departure from the Vitruvian concept of a module.[7] Moreover, due to the absence of common mathematics that systematically explains the actual proportions, the existence of proportional systems regarding Roman architecture is legitimately denied.[8] Considering the discrepancy between ancient theory and practice, as well as the current level of scientific knowledge, this paper aims to present the results of the research that attempts to examine the possibility of canonized determination of actual proportions regarding elements of historical architecture according to Vitruvius' indications about the concept of the module, but with one exception. Divergent from the idea of congruent modules, the concept of systematic application in the same scale of different NVs is proposed, specific to the proportions intrinsic to the geometric figures associated with the elementary *ad triangulum* method – historically not linked to the proportioning of Classical orders. The exact associated numerical values are derived from the following procedure: since 2 hexagrams joined with pairs of vertices (alternatively, an equilateral triangle mirrored at the base) form a rectangle with the proportional ratio of 1:1.732050807568877 (1:√3), the ratio of the height to the width of the hexagram (side to height of an equilateral triangle) is 1.1547005383792511 or (2/√3):1 (Fig. 2). Therefore, when the height of the upright hexagram has a value of 1 – corresponding to



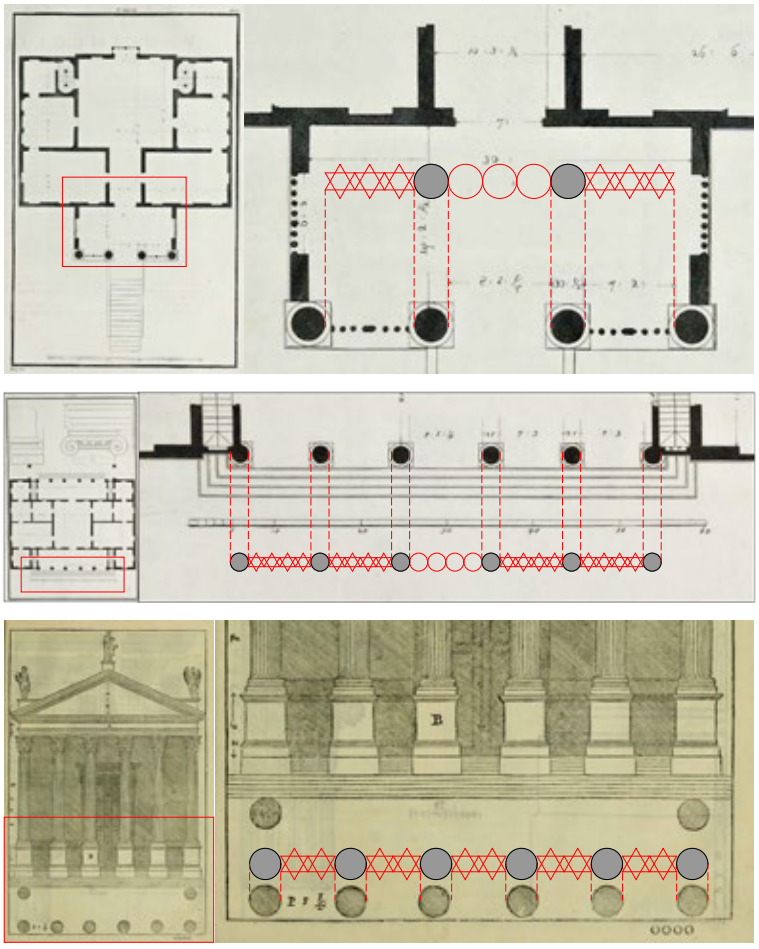
1
A geometric representation of Vitruvian nominal values for intercolumniation (Duško Čikara)

Geometrijski prikaz Vitruvijevih nazivnih vrijednosti za međustupovlje (Duško Čikara)



2
Calculation of the ratio of 1:1.1547 by geometry (D. Čikara)

Izračun omjera 1:1,1547 pomoću geometrije (D. Čikara)

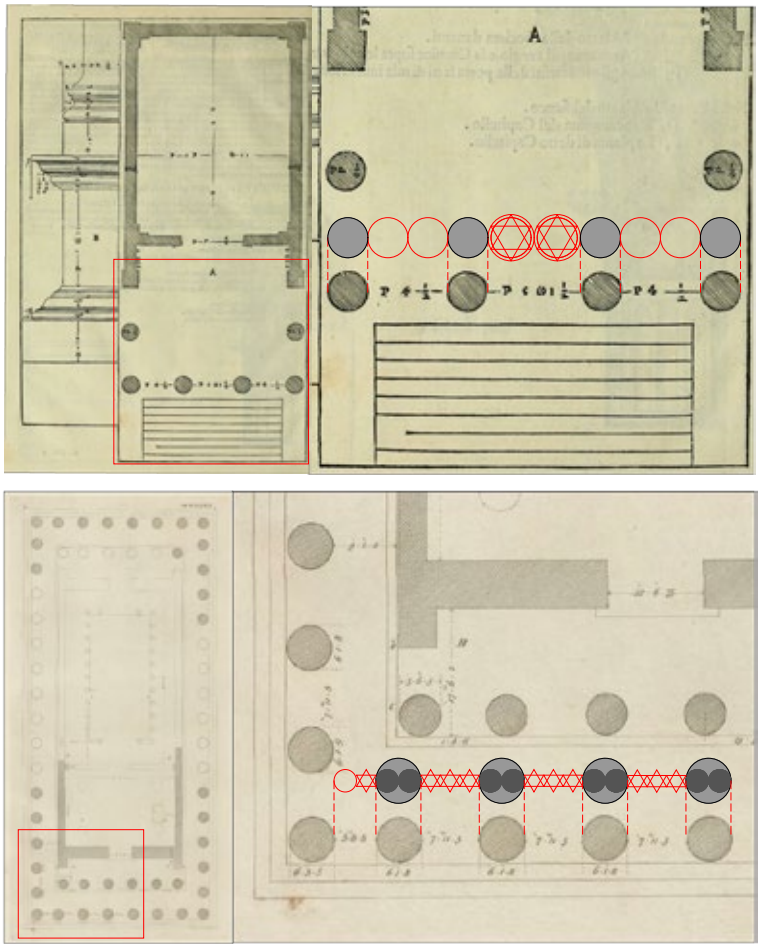


3
Andrea Palladio, Villa Chiericati at Vancimuglio, floor plan and detail (Ottavio Bertotti Scamozzi, 1781); A. Palladio, Villa Valmarana at Lisiera, floor plan and detail (O. Bertotti Scamozzi, 1778); The Temple of Minerva in Assisi, drawings and detail (A. Palladio, 1570) – overlaid with the proportional system by D. Čikara

Andrea Palladio, Villa Chiericati u Vancimugliju, tlocrt i detalj (Ottavio Bertotti Scamozzi, 1781.); A. Palladio, Villa Valmarana u Lisieri, tlocrt i detalj (O. Bertotti Scamozzi, 1778.); Minervin hram u Asižu, crteži i detalj (A. Palladio, 1570.) – preklopi s proporcijskim sustavom D. Čikara

the diameter of the circumcircle that represents the lower/bottom diameter of the column – the width has an exact value of 0.866025 or 1/1.1547 (for brevity, irrational numbers corresponding to proposed NV are initially written with 6 and then with 3 decimal places; the recalculated actual dimensions are the result of calculation operations with 6 decimal places).

The systematic research followed the experimentation on scanned historical plans of relevant edifices, where it had occurred that some *intercolumnia* correspond to sequences of CAD-generated hexagrams overlaid in the scale of the depicted column diameter.[9] The inference that the majority of unspecified actual *intercolumnia* are not simply arbitrary, but the result of the application of a mathematical system, was made after overlays with plans of Palladio's villas. In the etching of Villa Chiericati at Vancimuglio (Fig. 3 above), the central *intercolumnium* is 3 times a column diameter (hereafter: D) of the standard Vitruvian *diastylos*, but the lateral *prima facie* is obtained by intuitive horizontal tripling of upright hexagrams in the same scale.[10] Concerning the accuracy of the historical drawings it should be noted that, since there

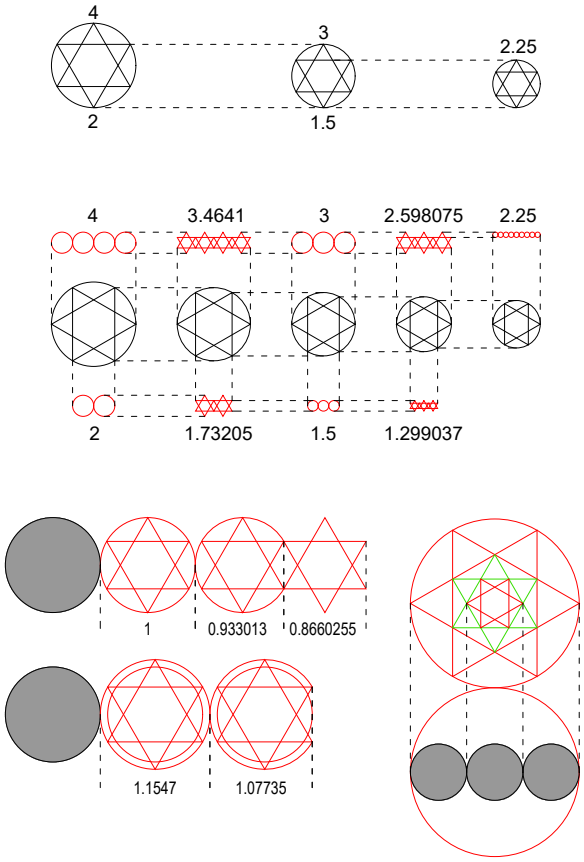


4
The Temple of Roma and Augustus in Pula, drawings and detail (A. Palladio, 1570); Iktinos and Kallikrates, the Parthenon, floor plan and detail (James Stuart and Nicholas Revett, 1787) – overlaid with the proportional system by D. Čikara

Hram Rome i Augusta u Puli, crteži i detalj (A. Palladio, 1570.); Iktin i Kalikrat, Partenon, tlocrt i detalj (James Stuart i Nicholas Revett, 1787.) – preklopi s proporcijskim sustavom D. Čikara

is no perfect manual drawing, it is always realistic to encounter some deviations. However, the NVs of wider *intercolumnia* of porticos in Villa Valmarana at Lisiera correspond to iterated 4 identical figures by the same alteration (Fig. 3 centre).[11] Furthermore, the equally divided portico of Temple of Minerva in Assisi on the woodcut by Palladio might be – except a single perceived and depicted shift – merely proportioned by doubled hexagrams (Fig. 3 below), although the inscriptions (*P2@10* or 34 inches and *P5¼* or 63 inches) suggest 1.852941D, a close approximation of 1+0.866 or a symmetrical 2×0.933013. The hypothesis of using ratios of the proposed geometric figures by ancients to determine intercolumniation is further inferred on Palladio's woodcut of temple in Pula. A detail of the column with the inscribed value just above the *apophyge inferior*, corresponding to the value within the section of the column on the floor plan of the temple (*P2¼* or 27 inches), points to the standardized position of the lower diameter (Fig. 4 above); it is presumed the sections in previous examples had been determined accordingly. The inscription of the central *intercolumnium* (*P6@1½* or 73.5 inches) suggests 2.722222D, a close approximation of 1+(2×0.866), although the NV as depicted is 2×1.154 or 2.3094D; within a diagram for the NV of 1.154, a concentric circle – corresponding to the width of the hexagram – subsequently determines a lower/bottom diameter. The inscription for the lateral (*P4½* or 54 inches) corresponds to the drawing. In descriptions Palladio has laconically rounded NVs according to Vitruvian terms.[12] The use of the discovered system in determining Greek Doric intercolumniation by the stated division of the diameter into 2 modules is indicated in the overlay with the first accurate plan of the Parthenon (Fig. 4 below).[13] The NVs of intercolumniation are elegantly determined by the tripling of 0.866 for the main and by the combination of 1 and 0.866 for the extreme *intercolumnium* in the N part of the W front. The correspondence between the drawing and the inscriptions is evident: the NV of the former could be 1.299038D [(3×0.866)/2], accompanied with measures in feet (7•11•5/6•1•8 or decimally in inches 95.32/73.5=1.29687), and the NV of the latter amounts to approximately 0.933D [(1+0.866)/2], the strict intermediate between the 1 and 0.866 – in feet 5•8•8/6•1•8 or 68.5/73.5=0.931972.

In the context of the general absence of explicit historical descriptions, for a certain proportional system to be convincing, several of the proposed scientific criteria have to be considered.[14] To fulfil the criterion of an indication in historical documents beside inference based on the forementioned inscriptions (criteria of simplicity, practicality and accuracy in the paradigmatic overlay of geometrical figures on historical drawings are already decisively fulfilled), the mathematical connection of NVs of Vitruvian *intercolumnia* and the applied geometrical figures – to the author's knowledge in an authentic way – was found crucial. The first step was to notice that NVs actually represent terms of 2 geometric sequences with a common ratio of 1.333333 (4/3) – the initial terms are 4 and 2, if the highest NV is in fact 4D. With a theoretical base in Vitruvius' emphasis on the importance of geometry, accompanied by the assumption that in ancient times proportional systems in architecture – as a visual discipline – were derived from primitive regular geometric figures as universal symbols of a higher order, it is logical to infer that the sequences with the specified common ratio were actually selected according to the elegant depiction by the uniform division of the vertical axis of the circumscribed upright hexagram into 4 parts (Fig. 5 above). In order to obtain *intercolumnia* with NVs that reflect the proportions of geometric figures intrinsic to the *ad triangulum* method, the detected geometric sequences were simply converted



5
Hexagram-based construction of the geometric sequences, consisting of Vitruvian nominal values, with a common ratio of 1.333333; hexagram-based construction of the geometric sequences, including Vitruvian nominal values, with a common ratio of 1.1547; fixed module in relation to the components with the hexagram-based values; the simple division into thirds by hexagram (D. Čikara)

Konstrukcija geometrijskih nizova metodom *ad triangulum*, koji se sastoje od Vitruvijevih nazivnih vrijednosti, s količnikom 1,333333; konstrukcija geometrijskih nizova metodom *ad triangulum*, koji uključuju Vitruvijeve nazivne vrijednosti, s količnikom 1,1547; zadani modul spram sastavnica s nazivnim vrijednostima temeljenim na heksagramu; jednostavna podjela na trećine pomoću heksagrama (D. Čikara)

into sequences with a common ratio of 1.154 (√1.333) by inserting intermediate terms derived from the identical figure (Fig. 5 centre). *Ergo*, since the latter sequences contain the hexagram-based NVs presented above, Vitruvian NVs are decoded as alternate terms – deliberately extracted – that represent commonly understandable small integers and simple fractions convenient to fulfil the postulates of *firmitas, utilitas* and *venustas*.

During the heuristic research the theory was expanded because it appeared that NVs of actual *intercolumnia*, not belonging to the terms of the initial theoretical sequences, comprise of multiple NVs 1.154, 1 and 0.866 (the terms of an analogous sequence, from the common ratio intrinsic to the geometry) e.g. 2×1.154=2.309D, 5×0.866=4.330125D, 6×0.866=5.19615D; with only the latter two terms in different combinations, e.g. 2+(3×0.866)=4.598075D, 3+(2×0.866)=4.732D. It must be noted that the NVs consisting of specific sequences of hexagrams practically correspond to simple fractions (2.59 and 4.33). As another strict intermediate, between 1 and 1.154, the NV of 1.07735 [1+(2/√3)/2] is included – also elegantly visualised by a hexagram-based diagram (Fig. 5 below left).

If found appropriate to obtain an actual NV of *intercolumnium*, the lower/bottom diameter – beside 2 and 4 congruent modulus with the NV of 1 – can be simply divided in 3 by the structure of the hexagram (Fig. 5 below right).

According to the proposal the sequenced units are not modules, but are defined as units of a method of modulation – with the selected element of architecture retaining the NV of 1. Mathematically, the concept is comparable to the system based on the iteration of squares in a manner of concentric rotation (*quadrangulatio*). Dependant on the sequencing of one NV or a combination (2 or even 3), modulation is static or dynamic.[15]

The scope of application also requires clear definition considering the fragmented theory. First, in contrast to the meticulous enumeration of the proportions of the smallest elements in the elevation of a temple (III, 5, *1–3*, *5–7* and *9–12*; IV, 1, *1* and *11–12*), the length of the column shaft –regarding the lower diameter – was not stated. The 8½:1 for Ionic colonnades in profane architecture (V, 9, *4*) is the exception. Despite the intriguing fact that Vitruvius greatly omitted to theorise the proportional length, from a logical point of view the shaft is considered to be an indispensable component within the theory. Due to constructive and architectural analogies of colonnades and fenestration interpreted as a symbol of Passage, relating the concept of the module to intercolumnar plane was extended to determine actual proportions of fenestration. Therefore, the stated proportioning of doorways (IV, 6, *1–6*) was also considered elementary. Since carved framing of colonnades and fenestration is derived from the primordial construction system of post-and-lintel, the proposed system – besides clear distance – implies the definition of the height of a column shaft or jamb/jamb shaft. Therefore, within articulated supports bases and capitals are not considered (Fig. 6). The front of a jamb or a jamb shaft (hereafter: F) is, analogously, selected as the fixed *module*.

It is logical to presume that the proposed mathematical deciphering of actual proportional ratios of the above architectural elements – hitherto interpreted as the result of not-so-great execution or, regarding Vitruvius, a departure of architectural practice from theoretical foundations – inevitably impacts the proportions of the totality. Therefore, the discovery of the principle of arranging components (hereafter: Modulation) simply derived from the elemental geometry, which could have been skilfully camouflaged in a

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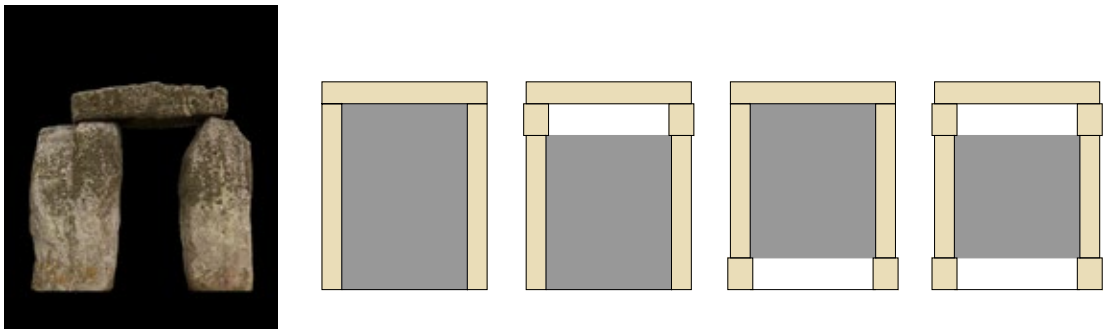


A segment of Stonehenge at Amesbury (The United Kingdom), the primordial construction system of post-and-lintel (D. Čikara after Diego Delso, delso. photo, License CC BY-SA, 2014); the relevant zones for proportioning intercolumnar plane and clear opening of fenestration by the proposed system regarding articulation of supports (D. Čikara)

Dio Stonehengea u Amesburyju (Ujedinjeno Kraljevstvo), praiskonski gredni konstrukcijski sustav (D. Čikara prema: Diego Delso, foto: CC BY-SA, 2014); bitne zone za proporcioniranje međustupovne ravnine i svijetlog otvora fenestracije glede raščlambe nosača (D. Čikara)

concept supposedly based on arithmetics within an invaluable historic source for the theory of architecture, might represent a significant theoretical contribution to the study of proportional systems in historical architecture.[16] Since Modulation is also indicated in the above prominent oeuvre from Cinquecento, the possibility of the continuous application from Antiquity arose – regardless of Vitruvius, especially if presumed that the parts of the treatise relevant to the concept of the module are integrally copied until the dissemination in the Renaissance. It was therefore considered appropriate to examine the persistent application within an extended period, including residential architecture, although the focus had been primarily on Classical temples, largely existing in the Vitruvian epoch. Accordingly, the selected sample of applied Modulation is presented, from the beginning of late Antiquity and the departure from the canon, to the 11th–15th century and the 16th–18th century periods of contrasting attitudes towards Classical Antiquity.

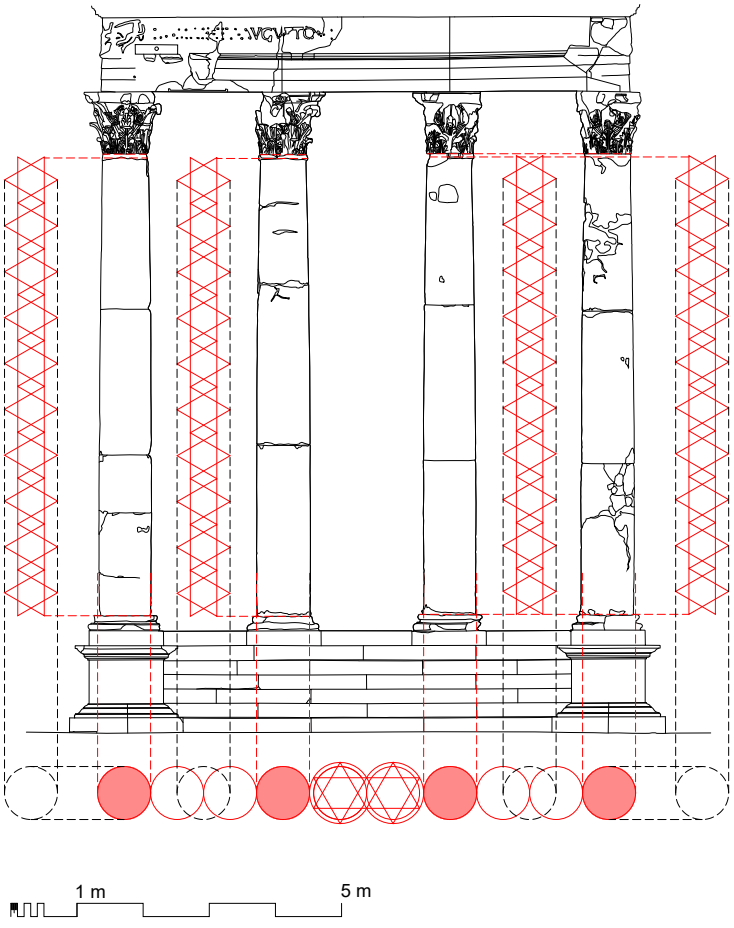
To meet the criterion of comparability, in order to assess the extent of chronological and geographical application of the Modulation within the limits of the article, sufficiently accurate numerical data and architectural documentation from independent modern surveys proved crucial beside archival data. The hypothesis is, for the sake of greater accuracy, tested by overlaying CAD geometric diagrams with relevant CAD drawings.[17] Regarding high technology, significant deviations from the actual state are not expected. Irregularities should be considered as an inevitable consequence of imprecision in the diverse stages of design and construction: from the drafting, translation of the unit of measurement, poor manufacturing, to the installation. Factors such as erosion or destruction followed by anastylosis should also be considered. The particular selection of precise surveys, produced mainly for conservation/restoration purposes, is deliberately partially inconsistent from the aspect of art history to minimize idiosyncrasy and coincidence. The metric values of all dimensions in question are thoroughly recalculated, since the mensuration (metrological analysis) is essential for the research – primarily in order to confirm the hypothesis of the exclusive derivation of specific proportional ratios (obtained by addition of rational and irrational numbers intrinsic to Modulation) of clear distance from a dimension of material component (diameter or front), presumably precisely executed in the finest practical contemporary unit of measurement. Secondly, to prove that the actual clear distance in question – determined by Modulation – is conversely rounded in a convenient manner. Therefore, the relevant dimensions, including those stated in feet (*piedi*, P) and spans (*palmi maiores*, ¾ of a foot), are converted into digits (*dita*, 1/16 of a foot). The non-anthropomorphic *minuto*, obtained by the division of an inch (*oncia*, 1/12 of a foot) in quarters, is presumed to be the finest proper unit.[18] According to the mutual ratio of 12:16 between inches and digits, a *minuto* enables setting i.e., carrying out in practice of measurements in thirds of a digit (0.25 *oncie* equals 0.33 *dita*, 0.50=0.66, 0.75=1, 1=1.33, 1.25=1.66, 1.5=2, 1.75=2.33, 2=2.66, etc). Quadripartite and the derived tripartite structure of a hexagram optimally suits the anthropometric, duodecimal system of measurement due to the elegantly divisible longer axis in equal parts.[19] It has to be considered that metrological values differ chronologically and geopolitically; e.g. the values of Doric and Roman feet are not reliable – the latter varies considerably, from 0.293 m to 0.2975 m.[20] Therefore from the earlier periods in the sample, only the NV of Modulation is reported. More accurately determined is the metric value of a Venetian *piede*; 0.34672 m from the 15th–17th century and 0.34776 m in the 18th century.[21] *Dito* accordingly amounts to 0.02167 m and 0.021735 m.

The concept of dividing the bottom diameter into modules by Ancient Greeks, inferred in the plan of the Parthenon – for the exclusive purpose of determining clear distances by the NVs of Modulation on condition of the denser disposition of columns – is evident by clear distances calculated with the compiled data

(interaxial distances related to the presumed bottom diameters) from independent surveys of a dozen Doric temples (Table 1).[22] The relation of simpler division into modules to the temples of Athena, Zeus and Hera is remarkable. The systematic use of Modulation in Doric order is indicated by the geometrically determined proportion of the column shaft calculated upon the measurement of the bottom diameter (1.555 m) and the reconstructed height (8.885 m) of the 6-drum shaft from the Temple of Athena Alea in Tegea. The height of the *trachelion* (0.138 m), added to the top in regard to fluting, results in the total height of 9.023 m.[23] According to the data, the actual NV is 5.802572D (≈5.799038 or 4+0.933+0.866).

For further examination, compiled numerical data relating to the values of the lower diameters and *intercolumnia* of Capitoline temples are considered as credible (Table 2).[24] Again, the values are first converted from interaxial to the values of clear distances. Since most of the *intercolumnia* in question are too narrow to be expressed by the smallest possible combination of NV of Modulation, a solution is again found in the proposed division of the lower diameter into modules that resulted in unexpectedly acceptable deviations from measured/reconstructed dimensions. The most evident sign of the actual application of the proposed system are NVs of the slightly different frontal and flank *intercolumnia* of the Temple of Venus Genetrix, obtained by inversion (0.866+1+0.866 and 1+0.866+1).

To examine the systematic use in Roman provincial architecture from the turn of the millennium, Modulation is overlaid with a drawing based on a 3D scan of the Temple of Roma and Augustus in Pula (Fig. 7). It is to be noted that the portico was bombed during WW II and was soon after reassembled.[25] Therefore, deviations in *intercolumnia* and in the dimensions of the shafts can also be attributed to the damage and extensive reconstruction, and not only to the usual conditions. Of the 6 shafts, 4 are 0.800 m in diameter and the remaining are 0.780 m. Since the *apophyge inferior* (together with the fillet) is lost on all columns, the accurate lower diameter is calculated by measuring the upper diameter of the shaft, thanks to the 4 preserved *apophyge superior*. The Vitruvian proportional system of diminution is applied; for the category of columns tall between 20 and 30 feet, the ratio between the upper and lower diameters is 6:7 (1:1.166666).[26] Considering that the frontal columns have a total height of approximately 8.150 m and that the frontal 3-drum shafts are 6.979 m, 6.980 m and two 6.965 m tall and that the best preserved upper



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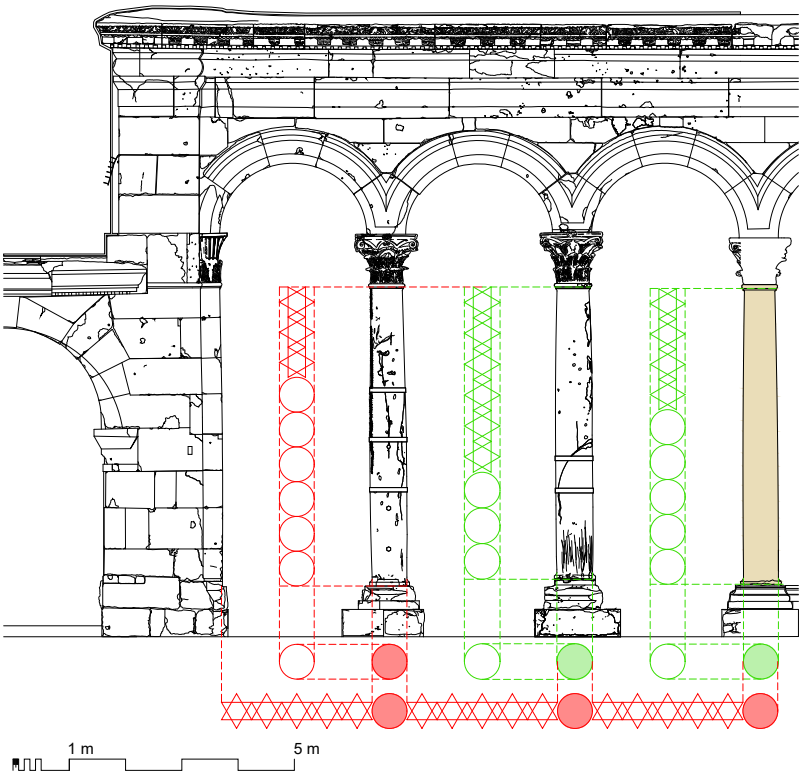
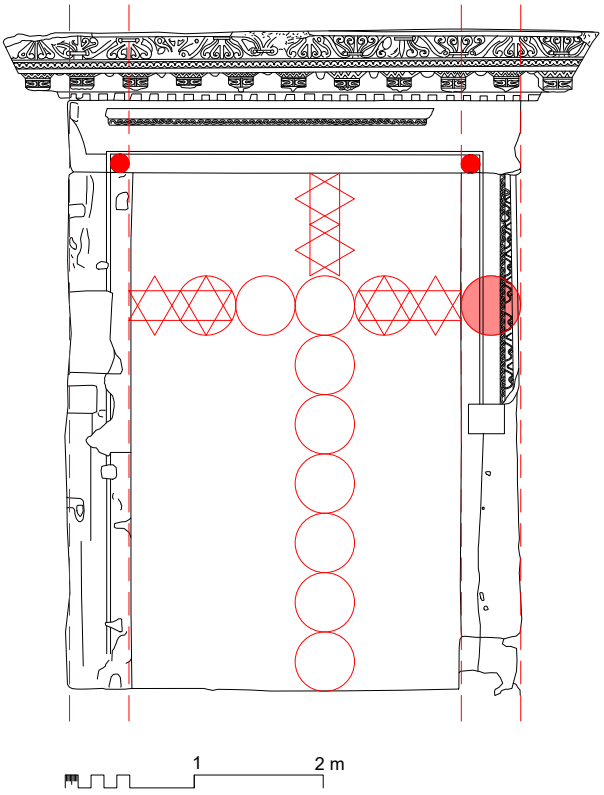
Front colonnade of the Temple of Roma and Augustus in Pula (Croatia) overlaid with the proportional system (D. Čikara, architectural drawing: VEKTRA d.o.o. Varaždin)

Čeono stupovlje hrama Rome i Augusta u Puli preklopljeno s proporcijskim sustavom (D. Čikara, arhitektonski crtež: VEKTRA d.o.o. Varaždin)

diameter (on the left shaft of the central *intercolumnium*) is 0.687 m, then the ideal lower diameter should be 0.801 m – the virtually insignificant difference confirms the implementation of the system. Since the closest NV from Modulation to the actual state is 10×0.866=8.66025D (0.801×8.66=6.936 m), the lengths of the shafts relative to the established lower diameter could have been determined excluding the 0.059 m thick astragal, although they are carved from the same block (completely destroyed on the corner shafts).[27] Therefore, the relevant total heights of the shafts, including the upper fillet, are 6.920 m, 6.921 m and 6.906 m. It can be assumed that the difference is due to rounding down to a convenient unit of measurement or the anastylosis. The mutual difference of 0.014 m points to the latter. The central *intercolumnium* is 1.700 m and the lateral are 1.600 m. If the NVs of Modulation are scaled to the diameter of 0.8009 m, actual central *intercolumnium* closely approximates 2.1547D or 2×1.077D (1.726 m) and lateral 2D (1.602 m).[28]

An overlay with the drawing of the view from the W of the northernmost part of the eastern arcade of the





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Northernmost part of Eastern colonnade of the Peristyle of Diocletian's Palace in Split (Croatia), view from the W overlaid with the proportional system (D. Čikara, architectural drawing: Croatian Conservation Institute)

Krajnji sjeverni dio istočnog stupovlja Peristila Dioklecijanove Palače u Splitu, pogled sa zapada preklopljen proporcijskim sustavom (D. Čikara, arhitektonski crtež: Hrvatski restauratorski zavod)

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Northern portal inside the Vestibule of Diocletian's Palace in Split (Croatia) overlaid with the proportional system (D. Čikara, architectural drawing: GEODATA d.o.o. Split)

Sjeverni portal unutar Vestibula Dioklecijanove Palače u Splitu preklopljen proporcijskim sustavom (D. Čikara, arhitektonski crtež: GEODATA d.o.o. Split)

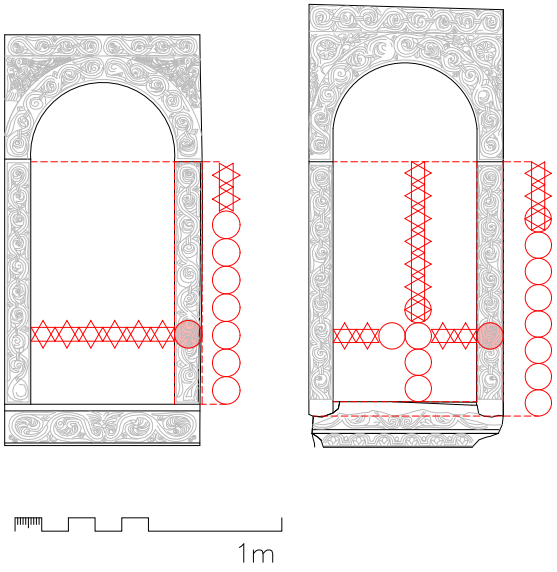
Peristyle of Diocletian's Palace in Split built around 300 AD is performed to detect geometry in the proportions of the likely re-used monolithic Classical shafts, but also the possibility of a wider use of Modulation – since it is not a temple. The drawing is the result of combining precise methods of survey (Fig. 8).[29] Starting from the N, shafts (two from Greek marble and one from a red granite) of 0.618 m, 0.634 m and 0.621 m in diameter are 5.315 m, 5.196 m and 5.258 m tall – both fillets included and astragals excluded. The NVs of 8.600323, 8.195583 and 8.466989 correspond to 8.598075D that would amount to 5.314 m (8.598×0.618), then to 8.19615D that would amount to 5.196 m (8.196×0.634) and finally to 8.4641D that would amount to 5.256 m (8.464×0.621). Besides the strong indication of Modulation, it is worth noting that the inversion of the NVs 1 and 0.866 in determining the lengths of the marble shafts points to a certain system of gradation, presumably within the same original edifice. The intercolumniation, in the same order, is 2.661 m, 2.665 m and 2.683 m wide. Since the lower diameters differ, it is difficult to determine the intended NV. The closest NV from Modulation is 4.330D, if a lower diameter of 0.618 m was selected as referential. The product is a clear span of 2.678 m. The deviation in relation to the measured distances – a possible consequence of imprecise placement of

columns, with different diameters being an aggravating circumstance – is 0.02 m, 0.01 m and 0.01 m (less than 1%).

To examine the fenestration, Modulation is overlaid with the late Roman portal inside the Vestibule of Diocletian's Palace in Split. According to the drawing based on computer-generated orthogonal photography referenced by total station (Fig. 9), non-articulated jambs of unequal fronts (the left is 0.506 m and the right is 0.461 m wide) are aligned with the outer edges of the lintel (a somewhat more massive, 0.562 m). Therefore, as a relevant detail for establishing their intended width, the distance of the astragal strip on the lintel – in relation to the upper and side edges of the clear opening – is selected starting from the logical assumption that it should be identical. Accordingly, the right jamb occurs to be more relevant. The clear span, after the correction amounting to 2.577 m, might have been obtained by rounding down the NV of 5.598075F (0.461×5.598=2.580 m) and the height of the opening (4.003 m) from the rounding down of the NV 8.73205F (0.461×8.732=4.026 m).

The survival of the ancient method is suggested by the overlay with the drawing based on a survey with total station of the highly carved proto-Romanesque monophore from 11th century on the E and N facades of St. Michael's, a court chapel at Ston.[30] Accordingly, only the wider right jambs (0.104×0.909 m and 0.099×0.901 m), inserted in the partial recesses in the sills, determine the proportions of the 0.539 m wide openings expressed by Modulation (Fig. 10). Lengths to the sill of the right jambs closely correspond to the NVs of 8.732F (0.104×8.732=0.908 m) and 9.129163F (0.099×9.129=0.903 m), and clear spans to the NVs of 5.19615F (0.104×5.196=0.540 m) and 5.4641F (0.099×5.464=0.541 m) in the same order. The chipped sill of the N window exposes total lengths of the jambs (0.953 m) that indicate a NV of 7+0.933+1.732=9.665063D (≈9⅔). Geometrically, the difference between the total and once visible length is a matter of replacing 4 circles with 4 hexagrams.

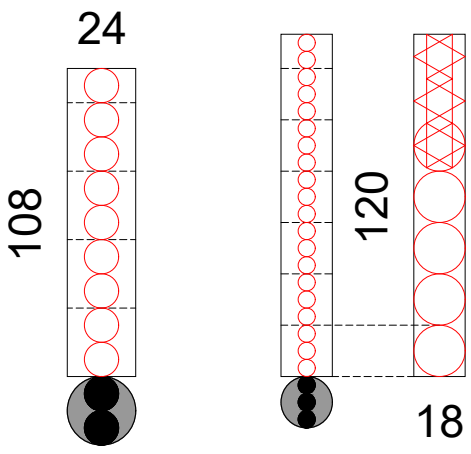
Another medieval sign of Modulation occurs in a contract from 1324, far before the renaissance of Vitruvius, wherein a stonemason and builder Vlaho Tomadov undertook the production of columns for a house in Dubrovnik. Since similar contracts usually confirm separate carving of capitals, the above probably referred to typical cylindrical shafts.[31] The lesser elongated is 9 *palmi* tall and P1½ in diameter and three are 10 *palmi* tall and P1 plus 2 *dita* in diameter. Although dimensions converted to digits (108/24 and 120/18) reveal simple fractions 4½



10

Eastern and Northern monophora of St. Michael's church at Ston (Croatia) overlaid with the proportional system (D. Čikara, architectural drawing: Croatian Conservation Institute)

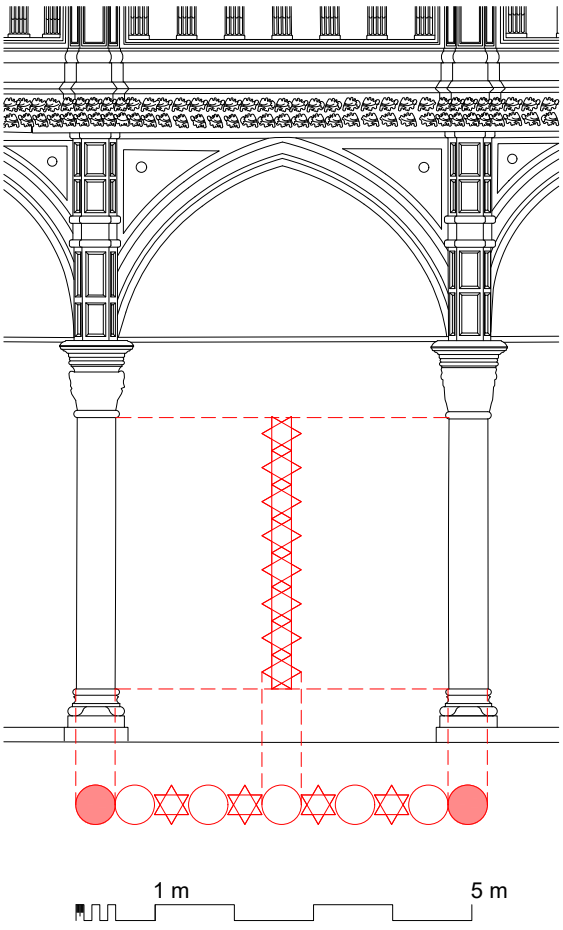
Istočna i sjeverna monofora crkve svetog Mihajla u Stonu preklopljene proporcijskim sustavom (D. Čikara, arhitektonski crtež: Hrvatski restauratorski zavod)



11

Geometric representations of the column shafts dimensions in digits from a contract in 1324 (Dubrovnik, Croatia) (D. Čikara)

Geometrijski prikaz dimenzija tijela stupova izraženih u prstima iz ugovora sklopljenog u Dubrovniku 1324. godine (D. Čikara)



12
The widest Northern nave arcade of Šibenik cathedral (Croatia), view from the South overlaid with the proportional system (D. Čikara, architectural drawing: VEKTRA d.o.o. Varaždin)

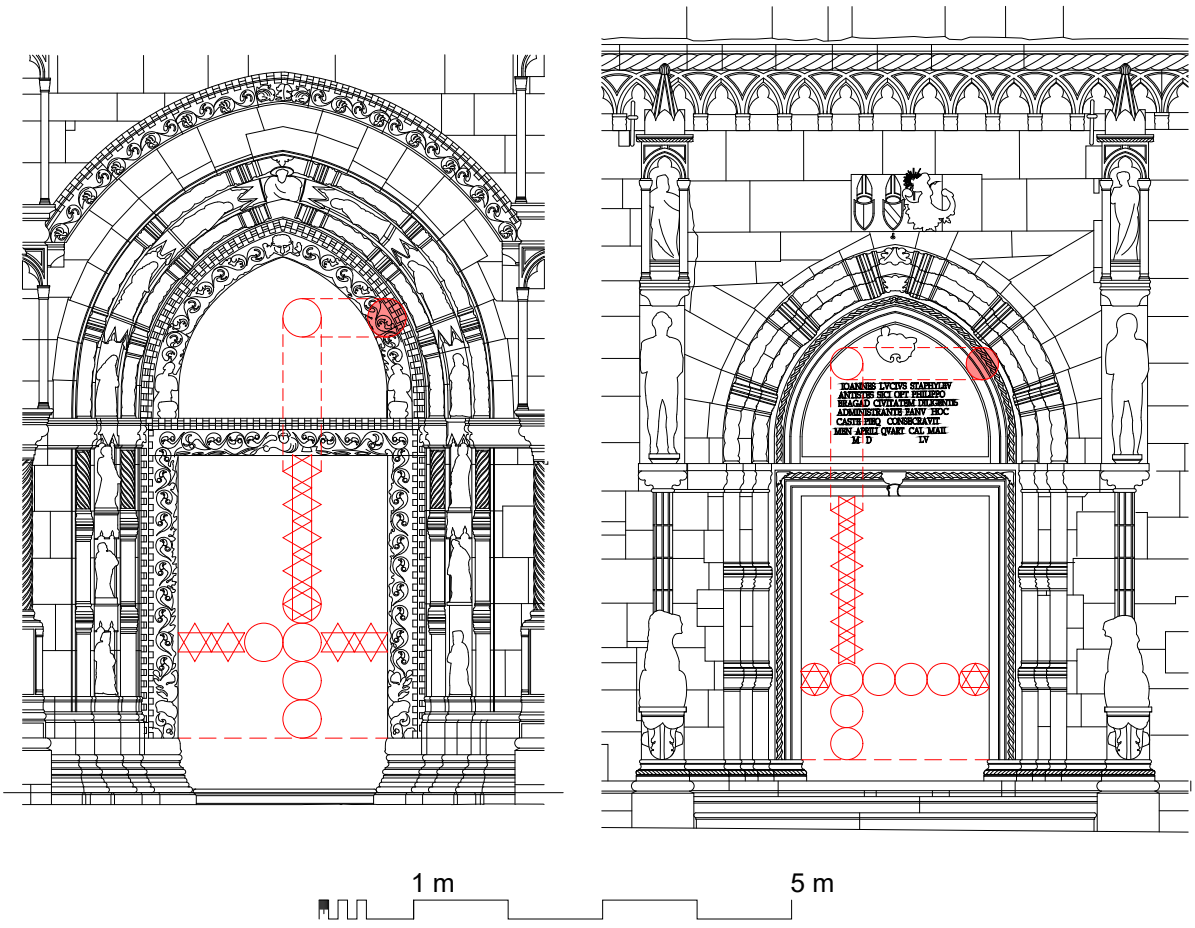
Najširi sjeverni luk u lađi šibenske katedrale, pogled s juga preklopljen proporcijskim sustavom (D. Čikara, arhitektonski crtež: VEKTRA d.o.o. Varaždin)

and 6⅔ (determined by congruent multiples, with a prerequisite division of the diameter into 2 and 3 modules), the latter could have been determined alternatively by 4+0.933+1.732=6.665063D since 18×6.665063=119.97 (Fig. 11). The impossibility of the same elegant alternative, regarding the former, points to the proposed division of a diameter by reason of a greater variety among proportionally shorter shafts, like in narrower *intercolumnia*.

The late medieval use of Modulation is indicated by the overlay with the 3D scan-based drawings of Šibenik Cathedral. The nave is divided by columns from the Gothic phase of construction (1431–1441).[32] According to the drawing of the N arcade, the diameters of 5 columns vary between 0.500 and 0.489 m, small deviations from 23 *dita* (0.498 m).[33] The cylindrical shafts, excluding *tori* and astragals, starting from the W are 3.434 m, 3.429 m (3 columns) and 3.41 m tall. Applying Modulation, the hypothetical NV could be determined by 8×0.866D (0.498×6.9282=3.450 m). The height corresponds to 159 *dita* or 3.446 m. The *intercolumnia*, in the same order, are 3.182 m, 3.179 m, 3.298 m, 3.179 m and 4.216 m, while the easternmost is 3.159 m. It can be concluded, after selecting a lower diameter of 0.498 m as relevant, that the largest *intercolumnium* should be 8.4641D (0.498×8.464=4.215 m, rounded to 194⅔ *dita* (Fig. 12). The Modulation is also overlaid with the contemporary W (Fig. 13 left) and N (Fig. 13 right) portals regarding the innermost frames. The evenly cut frames of pointed lunettes (0.406 m and 0.340 m) are selected as relevant since they exclusively determine the proportions by Modulation.[34] It can be considered that the intended fronts were 18⅔ *dita* and 15⅔ *dita* (0.405 m and 0.339 m). The clear spans of 2.212 m and 1.989 m almost have the exact NVs of 5.464F and 5.866025F, probably rounded to 102⅓ *dita* (2.217 m) and 91⅔ *dita* (1.986 m). Shafts are 2.991 m (perhaps 137⅔ *dita* plus joints) and 2.792 m (128⅓ *dita*) tall, close approximations of the NVs of 6.464+0.933=7.397114F (2.300 m) and 8.196F (2.787 m).

The use of Modulation in fenestration is again indicated by the overlay with the drawing of the W monofora from the *piano nobile* of the Moise Palace in Cres, attributed to the workshop Marangonich from the first half of the Cinquecento.[35] From the drawing based on digital photography referenced by total station, the jambs are not uniform, nor constant in width (Fig. 14 left). In addition to the deviation from the perpendiculars, they are unevenly installed in relation to the axis of symmetry, since below slightly protruding capitals jambs were usually to be positioned in the continuous plane regarding springing points of an arch. Therefore, the width of the frame at the springing points (0.161 m≈7⅓ *dita*) is selected as relevant. The diameter of the intrados (0.879 m≈40⅔ *dita*) corresponds to the NV of 5.464F (5.464×0.161=0.879 m). The shafts are 1.196 m and 1.204 m tall (≈1.199 m or 55⅓ *dita*), which resembles the NV of 7.4641F (7.464×0.161=1.202 m). The Modulation is again indicated on the basis of a recalculation, to the finest practical unit of measurement, of dimensions from the archived contract; in 1599 the stonemason Stjepan Bokanić undertook the cutting of monolithic columns P13½ tall and P2 minus 4 *dita* wide for the church of St. Simon in Zadar.[36] The stated certainly refers to shafts, for carving a complete column – especially of such dimensions – in a single cuboid of stone would be an irrational endeavour. The proportional ratio converted into digits is 7.714285 (216/28), a rounded-down NV of 7.73205D or 216.4974 digits (Fig. 14 right).

The persistence in proportioning of fenestration by Modulation is illustrated in the fortified Marinčević-Gligo complex at Bobovišće Luka on the island of Brač; the outline around 1740 is attributed to *protomagister* Ivan III. Macanović from Trogir.[37] The evenly cut



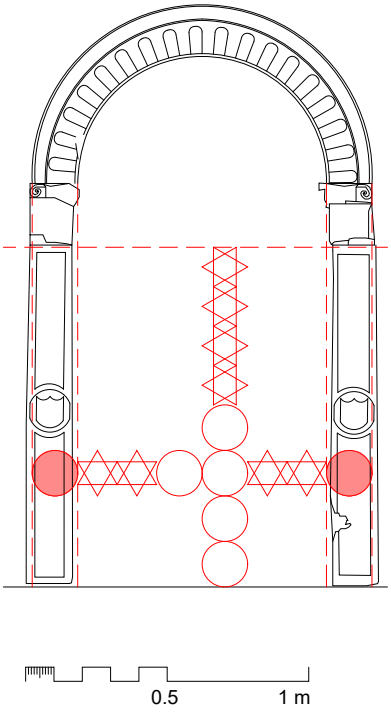
13
Western and Northern portal of Šibenik cathedral (Croatia) overlaid with the proportional system (D. Čikara, architectural drawing: VEKTRA d.o.o. Varaždin, 2013)

Zapadni i sjeverni portal šibenske katedrale prekopljeni proporcijskim sustavom (D. Čikara, arhitektonski crtež: VEKTRA d.o.o. Varaždin, 2013.)

fronts of the main portal jambs, surveyed with total station, amount to 0.289 m or 13⅓ *dita* (Fig. 15). The proportion of the clear opening (1.790×2.361 m or 82⅓×108⅔ *dita*) appears to be determined by simply adding 2F vertically (6.19615F×0.289=1.791 m; 8.196F×0.289=2.369 m) and subsequent rounding.

From Vitruvius's treatise it can be inferred that the design of particular elements of architecture – the proportions of column shaft along with the intercolumniation, as well as the proportions of the jamb/jamb shaft and the proportions of clear openings of fenestration – is based on the concept of a fixed module, specified as the column diameter or front of the jamb/jamb shaft. A literal interpretation that assumes the congruent multiples of the fixed module with a nominal value of 1 along with the nominal values determined in fractions – leading to the definition of a modular system as an arithmetic sequence – does not provide a satisfactory solution since the numerous actual proportions do not match the fragmented and inconsistent theory. What is missing or subsequently omitted – which proved crucial – is the proper method of manipulating the value of the fixed module. According to the results of this research, the ancient theory might have indeed been founded if the actual proportions of the elements in question are elegantly determined by multiples in the same scale of the value of 1 (represented by a circle) and the values of 0.866025 and 1.1547 (1:0.866025), intrinsic to a hexagram constructed by the *ad triangulum* method. Beside different combinations of the above values, if appropriate, intermediate values 0.933013 and 1.07735 may also be included. Due to the irrational ratios of geometric origin, the design system discovered and proposed here is not strictly modular, but a specific modulation of the value of the fixed module.

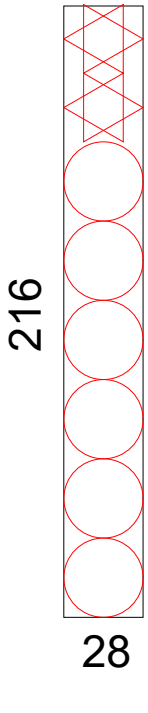
It can be argued that the results of this research exceptionally met the criteria set for proportional systems in historical architecture. In addition to the almost perfect match of the proposed system with the lower diameter-based proportions of several precisely surveyed Classical Antique shafts (astragal excluded) and intercolumniation, the numerical values obtained from independent surveys strongly point to a particular strategy: the intercolumniation of prominent Doric and Roman temples is determined by uniform division of the bottom/lower diameter in 2, 3 or 4 modules. It may be concluded that the unexplained



14

Monofora on the Northern façade of the Moise Palace in Cres (Croatia) overlaid with the proportional system; geometric representation of the column shaft dimensions in digits from a contract in 1599 (Zadar, Croatia) (D. Čikara, architectural drawing: University of Zagreb, Faculty of Architecture, Institute for Build Heritage)

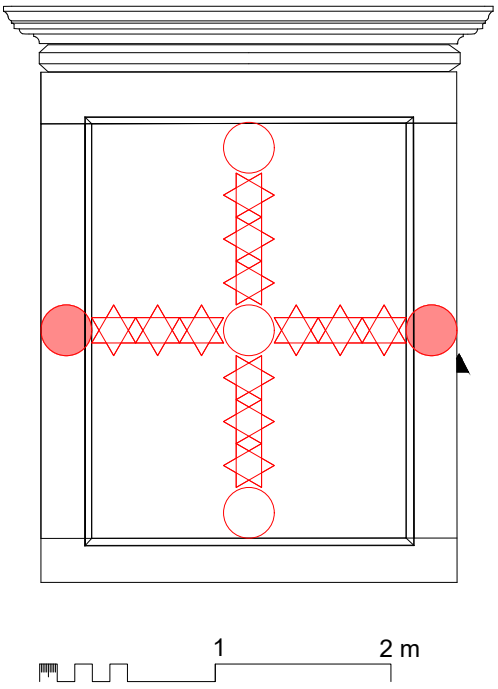
Monofora na sjevernom pročelju palače Moise u Cresu prekloplјena proporcijskim sustavom; geometrijski prikaz dimenzija tijela stupova izraženih u prstima iz ugovora sklopljenog u Zadru 1599. godine (D. Čikara) (D. Čikara, arhitektonski crtež: Zavod za graditeljsko naslijeđe Arhitektonskog fakulteta Sveučilišta u Zagrebu)



15

Portal of the fortified complex Marinčević-Gligo at Bobovišće Luka (island of Brač, Croatia) overlaid with the proportional system (D. Čikara, architectural drawing: Anka Ćurić)

Portal utvrđenog sklopa Marinčević-Gligo u Bobovišću Luci na otoku Braču prekloplјen proporcijskim sustavom (D. Čikara, arhitektonski crtež: Anka Ćurić)



division of the diameter of the Doric column into 2 modules made sense as a part of the solution to the issue of composing a large number of different narrow *intercolumnia* from the discovered system, currently the only logical reason for dividing the diameter into modules. As it is not probable that division of any length into a systematic sequence of irrational values follows the prior division of the same length by integers, a persistent presence of values derived from proposed system strongly indicates a methodological inversion regarding the established theory of designing a Greek Doric temple. Since the research so far suggests that Vitruvius should be taken *cum grano salis*, the strategy – not contradictory to the source, but logically derived from the specific postulate of dividing the diameter into 2 modules – warrants scientific validation. Furthermore, the proportions of a complete fluted zone of a Greek Doric column might have been determined by the proposed system. The architectural elements in question, derived from the primitive trabeated system, supports the hypothesis of the ancient canonical application of a rudimentary *ad triangulum* method. Therefore, the division of a column diameter into modules should be considered as a subsequent adjustment to denser colonnades, implying a non-Doric origin of the Modulation.

A more important discovery is the correspondence, given the high degree of accuracy regarding the samples, between the nominal values of the proposed

system that match architectural elements of Classical Antiquity and the fixed module-based proportions from the late Roman Empire to the 18th century. Accordingly, it can be concluded that the proposed system is not limited to supposedly distinct Graeco-Roman principles of architectural design – it might persist as canon in later periods. Conversely, the units of Greco-Roman metrology-in-practice might be inferred from the determination of the relevant dimensions in digits, documented in the 14th and 16th centuries. The hypothesis of extended use should be verified on a larger sample. Future research should also try to define a chronological and geographical framework in which the proposed system can be established by the same methodology, including the detected patterns. Different combinations of geometrically generated components derived from a fixed module to a great extent correspond to the actual proportions. Therefore, along with dimensions in the finest practical units of measurement, the proposed system explains perceived anomalies in construction and thus largely refutes the equally radical view of the nonexistence of proportional systems.[38] Considering the nominal values (resulting from specific repetition of hexagrams) that virtually correspond to fractions, a single mathematical method of encoding dimensions that were empirically recognized as suitable from the aspect of *firmitas* and *utilitas* is nevertheless the elegant way of obtaining final proportions by avoiding the division of the fixed module. Although, the observed inclusion of the single nominal value of 0.933 points to the ability of the proportion within a specified vertical support to be, if required, also expressed in simple fractions (Fig. 10 extreme right, 11 and 13 left). Although the proposed system does not seem to reflect philosophical ideas or religious symbolism of Antiquity, it can be speculated upon whether it – used with great discipline – fulfils a certain notion of *venustas* or even belief in a higher order since the process appears to always result in clear distances determined by symmetric horizontal sequencing.

The proposed system allows for a new paradigm, that neither changes of style nor the evolution of a particular style necessitates a change in proportional system. Yet, the issue of widespread emulation of proportions or recalculation of the numerical values from extant buildings should be considered, given the proportions determined by the proposed system imposes itself as a prerequisite for such a reproduction. Therefore, it is logical to posit a rather limited repertoire of mathematical tools and strategies, although the existence of a "universal" system of proportions is a paradox in Western thought since it calls into question the axiom of individual creative activity and continuous change/progress based upon it.

Since none of the largely anonymous medieval *protomagistri* nor any famous individuals that would be expected to participate in humanist discourse left a usable description or drawing, the selectively restricted knowledge of a single common proportional system is presumed. The results show that architecture could have been systematically designed despite the general lack of descriptions, although Vitruvius' treatise cannot be judged without pause because it is not known if its integrity was preserved until the 15th century. But, regarding the theoretical achievements of early modern period treatises as manuals – the results of this research clearly invite a grounded re-evaluation – it can be said that they are primarily a display of intellectual power emulating the ancient literary model, not serving to elaborate essential theoretical knowledge of the profession. It should be examined closer, whether the proportions in architecture by *trattatisti* resemble an idiosyncratic design or the proposed system.

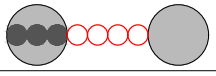
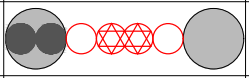
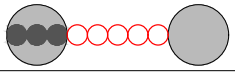
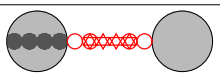
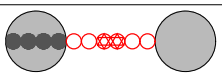
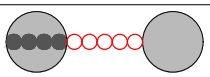
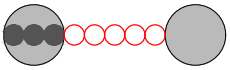
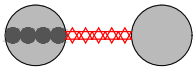
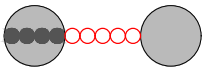
Location Temple	Measured clear distance (*typical interspacing minus bottom diameter*) in mm	D (*clear distance / bottom diameter*)	Proposed D (***proposed value*** / *modules in diameter*)	Geometric representation of proposed *intercolumnium*	Theoretical clear distance (error) (*proposed D × bottom diameter*) in mm
Tegea Ath. Alea *(front)*	2058 (*3613 - 1555*)	1.323472 (*2058 / 1555*)	1.333333 (***4*** / 3)		2073 (+15) (*1.333333×1555*)
Tegea Ath. Alea *(flank)*	2030 (*3585 - 1555*)	1.305466 (*2030 / 1555*)	1.299038 (***2.598075*** / 2)		2020 (-10) (*1.299038×1555*)
Assos Athena *(cent. front)*	1771 (*2685 - 914*)	1.937636 (*1771 / 914*)	1.933013 (***2+1.866025*** / 2)		1767 (-4) (*1.933013×914*)
Assos Athena *(flank)*	1533 (*2447 - 914*)	1.677242 (*1533 / 914*)	1.666666 (***5*** / 3)		1523 (-10) (*1.666666×914*)
Olympia Zeus	3005 (*5225 - 2220*)	1.3536 (*3005 / 2220*)	1.366025 (***1+1.73205*** / 2)		3033 (+28) (*1.366025×2220*)
Athens Hephaestus	1562 (*2580 - 1018*)	1.53438 (*1562 / 1018*)	1.532691 (***2+2.598075*** / 3)		1560 (-2) (*1.532691×1018*)
Bassae Apollo	1588 (*2725 - 1137*)	1.396657 (*1588 / 1137*)	1.399518 (***3+2.598075*** / 4)		1591 (+3) (*1.399518×1137*)
Sounion Poseidon	1500 (*2520 - 1020*)	1.470588 (*1500 / 1020*)	1.466506 (***4+1.866025*** / 4)		1496 (-4) (*1.466506×1020*)
Delos Apollo (Athenian)	1022 (*1832 - 810*)	1.261728 (*1022 / 810*)	1.25 (***5*** / 4)		1013 (-9) (*1.25×810*)
Rhamnous Nemesis	1185 (*1896 - 711*)	1.666666 (*1185 / 711*)	1.666666 (***5*** / 3)		1185 (*1.666666×711*)
Agrigento Hera	1704 (*3081 - 1377*)	1.237472 (*1704 / 1377*)	1.244016 (***2+1.73205*** / 3)		1713 (+9) (*1.244016×1377*)
Agrigento Concordia	1685 (*3105 - 1420*)	1.186619 (*1685 / 1420*)	1.183013 (***3+1.73205*** / 4)		1680 (-5) (*1.183013×1420*)
Agrigento Dioscuri	1328 (*2548 - 1220*)	1.088524 (*1328 / 1220*)	1.082531 (***4.330125*** / 4)		1321(-7) (*1.082531×1220*)
Segesta unfinished	2419 (*4354 - 1935*)	1.250129 (*2419 / 1935*)	1.25 (***5*** / 4)		2419 (*1.25×1935*)

Table 1

The relevant numerical values for intercolumniation in a sample of Doric temples and their geometric representation (D. Čikara)

Bitne brojčane vrijednosti za međustupovni razmak na uzorku dorskih hramova i njihov geometrijski prikaz (D. Čikara)

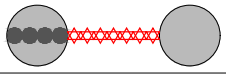
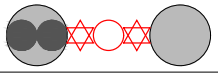
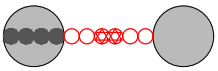
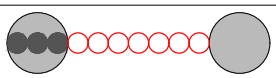
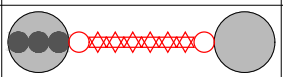
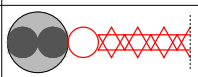
Temple inter-columnium	Reconstructed clear distance (*interspacing minus lower diameter*) in mm	Recalculated D after reconstruction (*clear distance / lower diameter*)	Proposed D (***proposed value*** / *modules in diameter*)	Geometric representation of proposed *intercolumnium*	Theoretical clear distance (error) (*proposed D × lower diameter*) in mm
Divus Iulius	1760 (*2920 - 1160*)	1.517241 (*1760 / 1160*)	1.515543 (***6.062175***/ 4)		1758 (-2) (*1.515543×1160*)
Venus Genetrix *front*	1700 (*2950 - 1250*)	1.36 (*1700 / 1250*)	1.366025 (***1+1.73205*** / 2)		1708 (+8) (*1.366025×1250*)
Venus Genetrix *flank*	1790 (*3040 - 1250*)	1.432 (*1790 / 1250*)	1.433012 (***2+0.866025*** / 2)		1791 (+1) (*1.433012×1250*)
Apollo Sosianus	2160 (*3630 - 1470*)	1.469387 (*2160 / 1470*)	1.466506 (***4+1.866025*** / 4)		2156 (-4) (*1.466506×1470*)
Saturn	3150 (*4500 - 1350*)	2.333333 (*3150 / 1350*)	2.333333 (***7***/ 3)		3150 (*2.333333×1350*)
Jupiter Optimus Maximus	3530 (*5000 - 1470*)	2.40136 (*3530 / 1470*)	2.398716 (***2+5.19615*** / 3)		3526 (-4) (*2.398716×1470*)
Jupiter Opt. Max. *central*	5930 (*7400 - 1470*)	4.034013 (*5930 / 1470*)	4.031087 (***2+6.062175*** / 2)		5926 (-4) (*4.031087×1470*)

Table 2

The relevant numerical values for intercolumniation in Capitoline temples and their geometric representation (D. Čikara)

Bitne brojčane vrijednosti za međustupovni razmak kapitolijskih hramova i njihov geometrijski prikaz (D. Čikara)

NOTES

1 Matthew A. Cohen, "Two Kinds of Proportion," in *Proportional Systems in the History of Architecture. A Critical Reconsideration*, ed. Matthew A. Cohen and Maarten Delbeke (Leiden: Leiden University Press, 2018), 19.
2 Mark Wilson Jones, *Principles of Roman Architecture* (New Haven and London: Thames & Hudson, 2003), 120.
3 Marie-Pascale Corcuff, "Modularity and Proportions in Architecture and their Relevance to a Generative Approach to Architectural Design," *Nexus Network Journal* 14 no. 1 (2012): 55–56.
4 Matthew A. Cohen, "Two Kinds," 19.
5 Vitruvius, *The Ten Books of Architecture*, tr. by Morris Hicky Morgan (Cambridge: Harvard University Press, 1914).
6 Gene Wadell, "The Principal Design Methods for Greek Doric Temples and Their Modification for the Parthenon," *Architectural History* 45 (2002): 1–8.
7 Within the limits of the paper, it is impractical to objectively select relevant literature concerning proportional systems of Roman architecture. The reader is referred to the book in note 2, which contains an extensive bibliography, and the book in note 1, considering relevant recent researches. The following article serves as a general introduction to proportional systems: Ralf Weber and Sharon Larner, "The Concept of Proportion in Architecture: An Introductory Bibliographic Essay," *Art Documentation: Journal of the Art Libraries Society of North America* 12 no. 4 (winter 1993): 147–154.
8 Mark Wilson Jones, *Principles,* 6.
9 To visualise the relevant NV, a hexagram is preferred over an equilateral triangle due to its biaxial symmetry.
10 Ottavio Bertotti Scamozzi, *Le fabbriche e i disegni di Andrea Palladio. Tomo terzo* (Vicenza: Francesco Modena, 1781.), T. XLVII.
11 Ottavio Bertotti Scamozzi, *Le fabbriche e i disegni di Andrea Palladio. Tomo secondo* (Vicenza: Francesco Modena, 1778.), T. XVIII.
12 Andrea Palladio, *I quattro libri dell'architettura. Libro quarto* (Venezia: Appresso Dominico de'Franceschi, 1570.), 103, 107.
13 James Stuart and Nicholas Revett, *The Antiquities of Athens. Volume the Second* (London: John Nichols, 1787), Ch.I.Pl.II.
14 J. J. Coulton, "Towards Understanding Doric Design: The Stylobate and Intercolumniations," The Annual of the British School at Athens 69 (1974): 61; Mark Wilson Jones, "Ancient Architecture and Mathematics: Methodology and the Doric Temple," in *Nexus VI: Architecture and Mathematics*, ed. Sylvie Duvernoy and Orietta Pedemonte (Torino: Kim Williams Books, 2006), 150–157.
15 Francisco Roldán, "Method of Modulation and Sizing of Historic Architecture," *Nexus Network Journal* 14 no. 3 (2012): 539–553.
16 Duško Čikara, "A Proposal for the Canonical Design of an Aisleless Floor Plan by Hexagram – a Dozen Vernacular Churches from the Island of Brač," in *Neglected Topics in Art and Humanities. Book of Essays in Honour of Professor Emeritus Vladimir P. Goss*, ed. Danko Dujmović and Palma Karković Takalić (Rijeka: University of Rijeka, Faculty of Humanities and Social Sciences: 2022), 73–74.
17 Grateful acknowledgment is given to architects Ivana Gobec and Ema Babić.
18 Andrea Palladio, *Libro secondo*, 4.
19 Duško Čikara, "A Proposal," 69.
20 Mark Wilson Jones, "Doric Measure and Architectural Design 1: The Evidence of the Relief from Salamis," *American Journal of Archaeology* 104 no. 1 (Jan. 2000): 74–75, 77.
21 Sanja Buble, "Istraživanje povijesnih mjera u Trogiru – mjere za dužine u arhitekturi rane renesanse," in *Zbornik Tomislava Marasovića*, ed. Ivo Babić, Ante Milošević and Željko Rapanić (Split: Sveučilište u Splitu and Muzej hrvatskih arheoloških spomenika u Splitu: 2002), 461.
22 Naomi J. Norman, "The Temple of Athena Alea at Tegea," *American Journal of Archaeology* 88 no. 2 (Apr. 1984): 172; Bonna Daix Wescoat, *The Temple of Athena at Assos* (Oxford: Oxford University Press, 2012), 38, 41; Mark Wilson Jones, "Doric Measure and Architectural Design 2: A Modular Reading of the Classical Temple," *American Journal of Archaeology* 105 no. 4 (2001): 702–710.
23 Jari Pakkanen, *The Temple of Athena Alea at Tegea. A Reconstruction of the Peristyle Column* (Helsinki: Department of Art History at the University of Helsinki and Finnish Institute at Athens, 1998), 13, 15, 17, 34.
24 John W. Stamper, *The Architecture of Roman Temples. The Republic to the Middle Empire* (Cambridge: Cambridge university Press, 2005), 126.
25 Ines Vanjak and Marko Špikić, "Principi restauriranja Augustova hrama u Puli 1946. i 1947. godine," *Godišnjak zaštite spomenika kulture Republike Hrvatske* 37/38 (2013): 8.
26 David A. Villa Domini, "The Diminution of the Classical Column: Visual Sensibility in Antiquity and the Renaissance," *Nexus Network Journal* 5 no. 1 (2003): 103.
27 Ines Vanjak and Marko Špikić, „Principi," 16.
28 A small difference from the actual lower diameter confirms that Palladio, while measuring in 16th C *piedi Vicentini* ($2^1/_4 \times 0.347\text{m} = 0.78075$ m), applied traditional methodology of determining the module. Regarding his higher NV of 2.309D for central *intercolumnium*, a recurrent clerical error is first to be assumed; since the lateral *intercolumnia* maintained the stated NV of 2D, it would have meant a significant contraction (0.1 m) of the whole front as a result of anastylosis, which is less likely.
29 Petar Puhmajer and Ivana Gobec, "Dokumentiranje stanja na sjeveroistočnom dijelu Peristila 2004. godine," *Godišnjak zaštite spomenika kulture Hrvatske* 31/32 (2007/2008): 45–46.
30 Ivana Tomas, "Nova promišljanja o crkvi Sv. Mihajla u Stonu," *Ars Adriatica* 6 (2016): 41–42, 45, 47–48.
31 Cvito Fisković, *Prvi poznati dubrovački graditelji* (Dubrovnik: Historijski institut JAZU u Dubrovniku, 1955), 80–81.
32 Predrag Marković, *Katedrala sv. Jakova u Šibeniku* (Zagreb: Naklada Ljevak, 2010), 160–161.
33 With the importance of the edifice and the involvement of foreigners in the construction, it is assumed that the measures were thoroughly determined in Venetian and not in local units.
34 The fronts of the monolithic jamb shafts of N portal amounts to 0.3502 m. On the W portal differ (0.417 m and 0.411), which is usual, since numerous examples have unequally wide jamb shafts of irregular outer edges.
35 Tea Sušanj Protić, "Renesansna kuća Moise u Cresu – rezultati konzervatorskih istraživanja 2011. godine," *Ars Adriatica* 4 (2014): 284–285.
36 The State Archives in Zadar; HR-DAZD-31, Bilježnici Zadra, Francesco Primizio (1590.–1608.), kut. 189, b. II, fasc. V, p. 43v–44r.
37 Duško Čikara, "Kasnobarokne reprezentativne bračke kuće tripartitnog tlocrta," in *Razmjena umjetničkih iskustava u jadranskome bazenu*, ed. Jasenka Gudelj and Predrag Marković (Zagreb: FF Press, 2016), 90, 97.
38 Rudolf Wittkower, "The Changing Concept of Proportion," *Dædalus* 89 no. 1 (winter 1960): 209.

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SAŽETAK

Dekodiranje Vitruvija — modulacija redane nazivne vrijednosti zadanog modula geometrijom *ad triangulum*

Najstariji spomen sustava razmjera za oblikovanje arhitekture zamišljenog na načelu dodavanja nalazimo u Vitruvijevom traktatu i to za određivanje nazivnih vrijednosti međustupovlja. Međutim, redanje krugova sukladnih (ravnomjerno podijeljenom) promjeru stupa – predodžba Vitruvijevog koncepta zadanog modula – daje iznose u cijelim brojevima ili razlomcima, koji ne odgovaraju znanstveno ustanovljenim nazivnim vrijednostima postojećeg ili rekonstruiranog svijetlog razmaka u stupovlju klasične starine. Svrhovitost se pokazala tek pokusnim uvrštenjem, u istoj skali, geometrijskih likova svojstvenih metodi *ad triangulum.* Potom je na dovoljno velikom uzorku postignut visok stupanj poklapanja zrcalnih nizova s točnim skorašnjim nacrtima te brojčanim vrijednostima neovisnih izmjera. Ovakav proširenI koncept primijenjen je za određivanje međustupovnog razmaka, uključivo dorski red, te odnosa promjera i visine tijela stupa. Sustav je, s istovjetnim rezultatima, odgovarajuće primijenjen na fenestraciju s obzirom na to da se stupovlje i uokvireni otvori mogu smatrati izvedenicama praiskonske gredne gradnje. Naznake korištenja otkrivenog sustava klasične starine na hrvatskom tlu do u 18. stoljeće – poput ugovorenih mjera za stupove koje su podudarne odgonetnutim nazivnim vrijednostima – dovode u pitanje zamisao o kreativnoj ulozi pojedinca glede određivanja razmjera jer upućuju na postojanje jedinog, nepisanog pravila za oblikovanje navedenih elemenata arhitekture zapadnog svijeta od grčko-rimskog doba – neovisno o tiskanoj inačici Vitruvijevog rukopisa koji je možda odavno prepravljen. Stoga će se i teorijski dosezi modernih traktatista, u slučaju poklapanja predloženog sustava s točnim nacrtima njihovih ostvarenja, ispostaviti tek kao puki iskazi moći uma prema drevnom predlošku.

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